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Prototype of an Advanced Ankle Proprioceptive Acuity Assessment Device

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Abstract - Body movement and balance are critical for daily activities; compromised balance leads to falls, especially among the elderly and those with neurological disorders like Parkinson's disease. Falls, a primary cause of unintentional injuries in older adults, are twice as common in Parkinson's patients. Many falls stem from impaired postural balance, often linked to compromised proprioception, heightening fall risk and fostering social isolation. Understanding sensory mechanisms is vital for effective fall prevention. A novel device, with two active platforms controlled by a microcontroller, assesses ankle proprioceptive acuity and tests postural perturbations, aiding in fall prevention strategies. The ankle proprioceptive acuity device boasts two independent active platforms with individual control, allowing concurrent assessment of ankle proprioception for both feet. To validate its functionality, we conducted kinesthesia assessments on six healthy individuals and two old people (Age >60). This measure serves as a key indicator of ankle proprioceptive acuity, ensuring the efficacy of the device's control system. The results of the kinesthesia assessments indicate that, on average, healthy individuals recorded a mean sense of motion score of 1.7 degrees per second with a standard deviation of 0.4, while older recorded a mean score of 7.2 degrees per second with a standard deviation of 0.7. These preliminary findings provide valuable insights into the device's functionality but are not statistically significant due to the small sample size. Nonetheless, these results lay the groundwork for future research. Moving forward, the device can be utilized to evaluate proprioception in both sitting and standing positions and introduce disturbances to further investigate balance and stability.

Keywords**:** Ankle joint, Proorioception, Postural balance, Proprioceptive Accuracy

1. Introduction

According to Burns, Stevens, and Lee [1], falls remain the primary cause of unintentional injuries among older adults and Parkinson's disease [2]. Postural balance loss accounts for a significant portion of falls [3]. According to Ambrose, Paul, and Hausdorff [4], one of the most frequent risk factors for fall accidents is impaired postural balance. According to a recent prospective study, older adults' risk of falling can be independently predicted by postural sway amplitude, a measure of postural balance [5]. Therefore, it is crucial to comprehend the mechanisms governing postural balance in order to prevent falls and assess fall risk. Postural balance maintenance involves multiple senses. According to Riemann and Lephart [6], proprioception is the sensory system that informs the central nervous system about the degree of motor activity, which is essential for maintaining postural balance. In fact, it has been noted that poor proprioception and poor postural balance are related [7]. Enhancing proprioceptive feedback through interventions has been suggested as a way to improve postural balance [8,9]. Priplata et al. [8], for instance, found that postural sway in both young and old people decreased during static stance after applying subsensory noise, which has been demonstrated to improve proprioceptive feedback [10] to the feet.

Various methods for examining proprioceptive mechanisms have been documented in the literature. Proprioception can be evaluated using three primary testing methods: active movement extent discrimination assessment (AMEDA), joint position reproduction (JPR), also referred to as joint position matching, [11], and threshold to detection of passive motion (TTDPM) [12]. These tests are administered in different ways, with varying testing conditions, and they may evaluate different facets of proprioceptive modalities[13,14, 15]. When the standard movement is removed and only the variable stimuli are shown, as in the single stimuli method, fewer trials are required. This technique turns into the method of ultimate judgement when the same quantity of responses and stimuli are applied. Waddington and Adams created the AMEDA to assess participants' proprioceptive awareness in differentiating between ankle inversion angles using the absolute judgement method. The AMEDA technique, which measures proprioception at the knee, hip, lumbar spine, cervical spine, shoulder, and hand, was developed and validated recently. When used in oral rehabilitation and

dentistry to evaluate proprioception at the jaw, the same technique is known as "interdental dimension discrimination." [16-20].

In this study, we aimed to test and use a prototype of an Active Ankle Movement Assessment (AAMA) that was designed and manufactured. Then, ankle proprioception acuity was measured by the device between the elderly and the control groups (healthy young people). It should be noted that previously, usually passive spring-supported platforms or one passive platform common to both limbs were used. The novelty of this project is the application of two active platforms, controlled independently by a microcontroller. Apart from the ankle movement assessment useful at the first stage of the research, the constructed device can be used to test the postural stability and sway at various excitations of the supporting ground.

2. Materials and Methods

The constructed ankle AAMA system will be utilized mainly to assess the proprioception of the participant's ankles while they are in a functional sitting position. To test the sense of position, predetermined ankle movements will be performed, ranging from the smallest to the largest, and the participants will be asked to indicate their responses using the assigned position numbers. To test the sense of motion, the minimum angular displacement required for the participant to perceive movement in either plantar flexion or dorsiflexion will be measured. The testing involved a sequence of trials, which will be performed at a very low angular speed (for instance, 0.5 degree/s) in which the participants will hold a push button and will be instructed to press it as soon as they perceive ankle movement and to indicate the direction of rotation. The constructed ankle proprioceptive acuity device (see Fig. 1) has two independent active platforms with independent controlling, enabling the simultaneous evaluation of ankle protection for both feet. To get some results and ensure that the control system of the device functions properly, we decided to assess the sense of motion (or kinesthesia) in six healthy individuals and two older as one of the ankle proprioception measures of acuity.

Table 1: Volunteers basic anthropometric data (EX ±SD).

	Healthy, N=6	Older, N=2
Age	25.6±1.7	62.5±2.1
Height (cm)	177.6±9.8	175±4.2
Mass (kg)	66.3±9.8	67.5±7.7

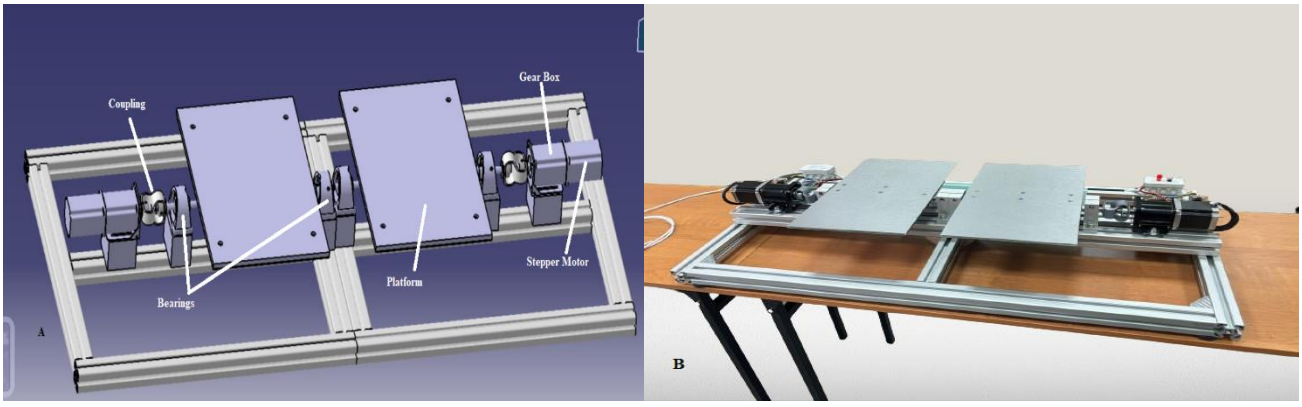

Fig. 1: (A) CAD design, (B) prototype of Ankle Assessment device

3. Results and discussion

The platform began to move with a constant speed of 0.5 degrees per second for the dominant foot of the volunteers, and when they felt the motion, they pushed the push button to record the results. This is how the sense of motion result was determined. According to the findings (Table 2), roughly six youthful, healthy participants, two Older have respective means and standard deviations of 1.7 and 0.4, and 7.2 and 0.7. According to the results, it is anticipated that measuring the proprioception of healthy and disabled individuals will show signifacnt changes in subsequent tests involving a larger sample size. These are only the device's preliminary results, so they cannot be statistically analyzed. Nevertheless, you can use it appropriately and conduct your own research to assess the proprioception of the two legs in sitting and standing positions and apply disturbances from it in the future study.

Table 2: Result of Sense of Motion.

Variable	Healthy	Older
Sense of Motion (SoM)	1.76± 0.42	7.2±0.76

4. Conclusion

In this study, we looked into the ankle proprioceptive measuring device's control performance. The results of the tests that were done are promising, and it is anticipated that the next study will be able to assess the intra-class correlation coefficient (ICC) using the device's results with a bigger sample size.

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